Defense Technical Information Center Compilation Part Notice

ADP010622

TITLE: Interface Issues in the Use of Virtual Environments for Dismounted Soldier Training

DISTRIBUTION: Approved for public release, distribution unlimited

This paper is part of the following report:

TITLE: The Capability of Virtual Reality to Meet Military Requirements [la Capacite de la rea1ite virtuelle a repondre aux besoins militaires]

To order the complete compilation report, use: ADA388966

The component part is provided here to allow users access to individually authored sections of proceedings, annals, symposia, ect. However, the component should be considered within the context of the overall compilation report and not as a stand-alone technical report.

The following component part numbers comprise the compilation report:

ADP010609 thru ADP010633

INTERFACE ISSUES IN THE USE OF VIRTUAL ENVIRONMENTS FOR DISMOUNTED SOLDIER TRAINING [2,3]

Bruce W. Knerr, Ph.D.
US Army Research Institute
12350 Research Parkway
Orlando, FL 32826, USA

ABSTRACT

In 1992 the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) initiated a program of in-house experimentation to investigate the use of virtual environments (VE) technology to train dismounted soldiers. Since that time, we have conducted thirteen experiments examining human performance in VE, training effectiveness and transfer of skills acquired in VE to the real world, and side-effects and after-effects of exposure to VE. The tasks used have included distance estimation, tracking, object manipulation, visual search, route learning in buildings, building search, and land navigation. This paper summarizes results from these experiments related to visual display characteristics and methods of locomotion.

The most common VE display systems, low- to moderate-cost head mounted displays (HMDs), limit performance with low resolution and small fields of view (FOVs). Performance on a variety of distance estimation tasks is significantly worse than performance on similar tasks in the real world. Providing stereoscopic view improves performance, but only at short distances. Increasing the field of view while holding resolution constant improves performance. Linking the viewpoint to head movements improves distance estimates and, under some conditions, spatial knowledge acquisition. For some tasks, performance using a monitor is better than performance using an HMD, while on other tasks, the reverse is true.

A variety of methods have been used to simulate walking in VE: joystick, spaceball, treadmills, and walking in place (with instrumentation to sense steps). Few direct comparisons of these methods have been made. For some tasks, a joystick combined with auditory cueing may provide an effective substitute for high-cost locomotion simulators.

INTRODUCTION

In 1992 the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) initiated a program of in-house experimentation to investigate the use of virtual environments (VE) technology to train dismounted soldiers. Since that time, we have conducted thirteen experiments examining human performance in VE, training effectiveness and transfer of skills acquired in VE to the real world, and side-effects and after-effects of exposure to VE. The tasks used have included distance estimation, tracking, object manipulation, visual search, route learning in buildings, building search, and land navigation. We have now reached the point in our program where it is necessary to synthesize what we and other researchers have found, draw conclusions, and make recommendations for the use of VE for Army training. We are now beginning that that process. While our primary interest is in the use of VE for training, it has been clear from the start that it would be necessary to pay particular attention to the human computer interface. This paper will present some preliminary conclusions about two types of interface devices: relatively inexpensive visual display devices and devices for the simulation of locomotion.

The original program objective was to improve the Army's capability to provide effective, low-cost training and rehearsal for Special Operations Forces and Dismounted Infantry through the use of virtual environments technology. Subgoals were to: focus on the requirements for individual soldier and leader accomplishment of unit tasks; determine the necessary characteristics of VE technology, including fidelity requirements; and evaluate transfer of training and performance to the real world. While we have consistently pursued these objectives over the life of the program, we have found them to be more complex than originally anticipated.

We describe our research program as a progression up the levels of a pyramid. Following an initial analysis of the task requirements for dismounted soldier training, and a review of the previous research in the use of VE for training (a very sparse area when we began), we conducted four experiments to investigate interface effects on the capabilities of participants to perform simple tasks in VE. Variables investigated included the type of control device, amount of practice on the tasks, stereoscopic vs. monoscopic helmet-mounted displays, and type of display device (monitor, boom, or helmet-mounted display). At the next level, we conducted two experiments that addressed the effectiveness

Paper presented at the RTO HFM Workshop on "The Capability of Virtual Reality to Meet Military Requirements", held in Orlando, USA, 5-9 December 1997, and published in RTO MP-54.

of VE for teaching the configuration of and routes through large buildings, and the transfer of the knowledge acquired to the real world. Taken together, these results led to an originally unplanned program of research into the investigation of distance estimation in VE. At the third level, we investigated the use of VE to represent exterior terrain, both for training land navigation skills (identifying landmarks and learning routes), and assessing threats. Research at the top of the pyramid (we have combined the top two levels) is investigating the use of VE for training team tasks. This experimental series is just beginning.

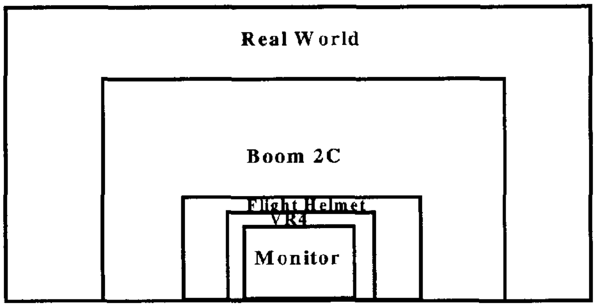

Figure 1. The relative sizes of the fields of view of various VE display devices

This paper will address two sets of interface devices: visual display devices and locomotion simulators:

There are four major characteristics of HMDs that seem particularly important:

- Resolution
- Field of View (FOV)
- Stereoscopic Vs. Monoscopic Vision
- Presence or absence of Head Coupling.

HMDs that we have used include the FakeSpace Labs BOOM2C, the Virtual Research Flight Helmet, and the Virtual Research VR4. HMDs differ in their use of color (the BOOM2C uses only two colors, not three), their resolution, and their FOV. Figure 1 shows the proportional size of the field of view of these HMDs relative to the normal human FOV and a 20" monitor viewed at a distance of approximately 24". Note that use of these devices restricts peripheral vision. The resolution of the displays is poor. Administration of an acuity test in VE has resulted in mean Snellen acuities of 20/500 and 20/860 for different versions of the VR Flight Helmet, and 20/200 for the BOOM2C (Lampton, Knerr, Goldberg, Bliss, Moshell, and Blau, 1994; Lampton, Gildea, McDonald, and Kolasinski, 1996).

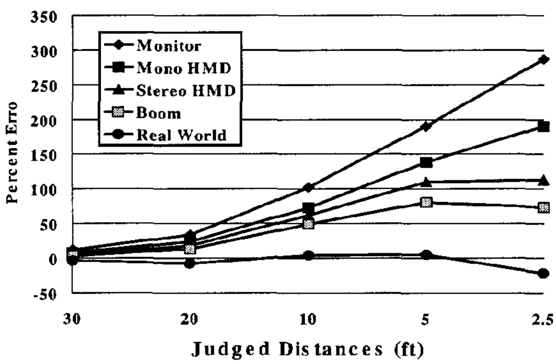

Figure 2. Percent error in distance estimates as a function of display device

VE DISPLAYS AND DISTANCE ESTIMATION

To determine the impact of these factors on performance in a realistic task, we developed a distance estimation task in which the human participant estimates the distance to a human figure as it moves toward them from a known distance of 40 feet. We did this with a number of different display devices in VE (using a virtual image of the human figure) and in the real world with a live human. Figure 2 combines the data from several different experiments (Lampton, Knerr, Goldberg, Bliss, Moshell, and Blau, 1994; Lampton, Gildea, McDonald, and Kolasinski, 1996; Singer, Ehrlich, Cinq-Mars, and Papin, 1995). Errors in the VE are in the direction of underestimating the distance to the figure (i.e., reporting it as being closer than it "actually" is). This seems to be consistent across all of the distance estimation tasks that we have used, with one exception to be described later. Significant differences among display devices are found more-frequently at the shorter distances. Performance generally improves with the increases in the field of view and resolution. Stereoscopic presentation improves performance only at distances shorter than 10 feet.

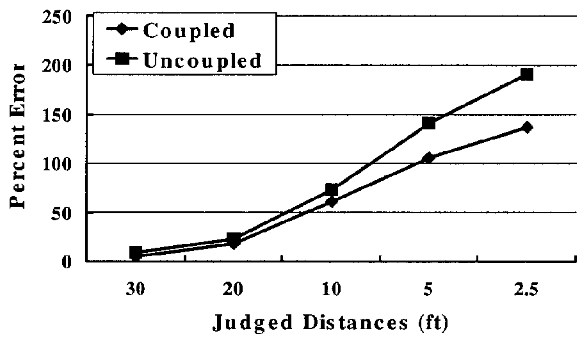

Figure 3. Percent error in distance estimates as a function of head coupling

As shown in Figure 3 head-coupling, or linking the field of view to head movements, also improves performance at the shorter distances (Singer, Ehrlich, Cinq-Mars, and Papin, 1995).

In order to examine the factors affecting distance estimation in VE more closely, and perhaps develop ways to improve distance estimation, Witmer and Kline (in press) used several other tasks. Figure 4 shows the results of an experiment in which participants were asked to estimate the distances to cylinders placed in a corridor at distances from 10 to 110 feet away. They underestimated the distances in both the real and virtual worlds, but underestimated them less in the real world.

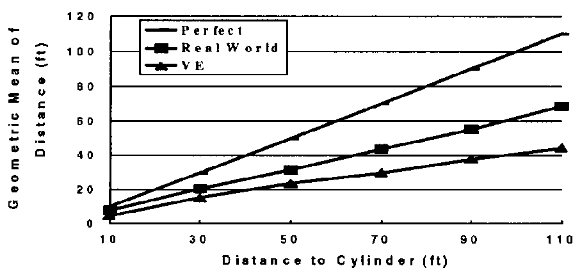

Figure 4. Distance estimates to a stationary object in a VE and the real world

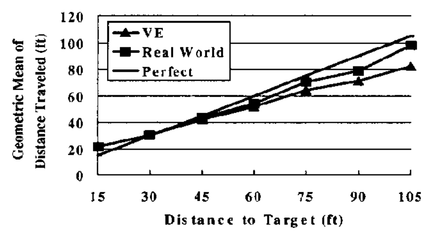

Figure 5. Distance traveled as a function of target distance

To what extent are these results due to participants' inability to provide good numeric distance estimates in any environment? Witmer and Sadowski (in preparation) used a different approach that asked participants to walk blindfolded to a target that they had just seen, instead of reporting the distance verbally. Participants in the real world condition viewed the targets, then walked the distance in a hallway. In the VE condition, they used a treadmill to walk a simulated hallway. Again, the participants underestimated the distances to the targets in both the VE and the real world (Figure 5).

They underestimated them more (i.e., were less accurate) in the VE. We can be confident, therefore, that these errors in distance estimation are not some artifact of the use of verbal reports of distance. However, it is interesting to note that the overall level of performance was better in this experiment than in the one described immediately before. Distance traversed in VE was about 85% of the true distance, while the verbal reports of stationary observers in the previous experiment were about 50% of the true distance.

It is difficult to examine the effects of the display device characteristics on human performance because we are limited to the characteristics of existing displays, which tend to differ on multiple dimensions, not just a single one. However, Kline and Witmer (1996) were able to use a software mask to create a smaller FOV for the BOOM2C, without changing any other characteristics. In this experiment, participants were placed in the VE in front of the end of a corridor (facing a wall), and asked to judge the distance to the wall. There was no corresponding real world condition. As shown in Figure 6, the narrow field of view condition (60 degrees horizontal x 38.5 degrees vertical) produced worse estimates than the wide field of view condition (140 degrees horizontal x 90 degrees vertical). It was the only condition in these experiments in which distances were overestimated in VE. A probable cause is the that the narrow field of view causes the loss of perspective cues which are important for distance estimation in this situation.

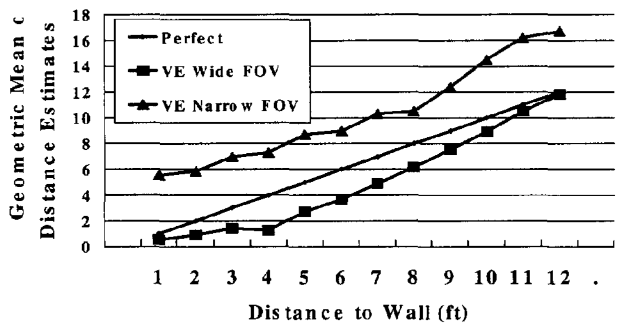

Figure 6. Distance estimates as a function of viewing distance and FOV

VE DISPLAYS AND PERFORMANCE ON OTHER TASKS

Other experiments have looked at how display characteristics affect performance on tasks other than distance estimation. Lampton, Gildea, McDonald, and Kolasinski (1996) compared a monitor, the BOOM2C, and the Virtual Research Flight Helmet in terms of performance on five tasks. Body movement and orientation were controlled by a joystick, with head coupling available for the HMD and Boom conditions only. The tasks were:

- Search -- Searching a room for a flying object while seated in the center of the room.
- Turns -- Moving through a narrow corridor which made a series of alternating left and right turns.
- Doorways --Moving through a series of rooms.
- Tracking --Moving a joystick-controlled pointer to a fixed target.
- Bins --Using a joystick to place an object in the correct bin.

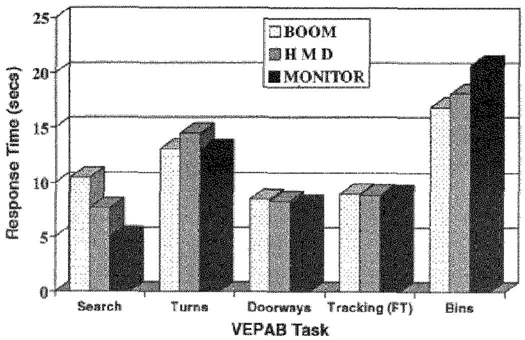

Figure 7. Time to complete selected VEPAB tasks as a function of display device

As shown in Figure 7, there were significant differences among these devices on only one task, the search task. Today's college students, perhaps because of their experience with video and computer games, appear to be quite proficient in searching a room while viewing it in a monitor and controlling their point of view with a joystick. The data are also a reminder that adding somewhat unstable mass to the head tends to affect head movements.

Simulating Locomotion in VE

Lampton, Knerr, Goldberg, Bliss, Moshell, and Blau (1994) compared the joystick and a spaceball to control locomotion through a variety of simple environments. Some involved "flying", and others did not. On every locomotion task, movement was significantly faster with the joystick (Figure 8)

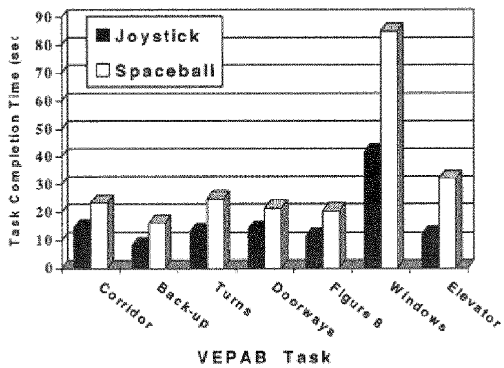

Figure 8. Locomotion task performance as a function of control device

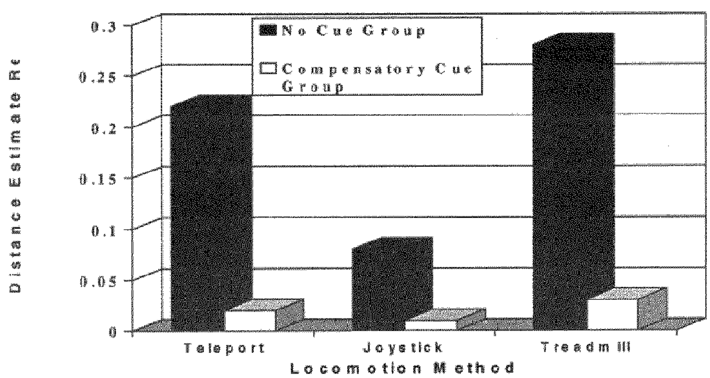

Figure 9. Error in distance estimates as a function of locomotion method and compensatory cueing

They attempted to keep travel time constant for all groups. The joystick moved participants forward at a fixed speed when pushed forward. Teleportees waited the same amount of time as moving the route by joystick required before they were teleported. Treadmill participants were instructed to maintain a fixed speed, and were automatically given recorded verbal reminders if their movement varied from that standard. When the auditory cues were present, the three groups did equally well. In the absence of auditory cues, the joystick group did best, and the treadmill group did the worst. The visual movement cues that the joystick group received are believed to be responsible for their superiority to the teleport group. The poor performance of the treadmill group is attributed to the workload required by the secondary task that they were given, that of maintaining a constant speed.

While much of the research has taken place in the simulated indoors, both simulated and real outdoor terrain were used in the investigation of spatial knowledge acquisition in VE. In the first experiment (Singer, Allen, McDonald, and Gildea, 1997), college students navigated one of two terrain areas, stopping at various locations along the route to learn to identify various landmarks. After the training, they were tested by being placed at new locations and asked to point to and estimate the distance to the same landmarks. There were three training conditions:

- High VE, using a head coupled HMD and the treadmill
- Low VE, using the same HMD, but without head coupling, and a joystick
- Map study

The performance of the college students, in terms of landmarks correctly located, was straightforward. The Hi-VE condition was significantly better than the map condition, with the Low-VE condition somewhere in between (Figure 10).

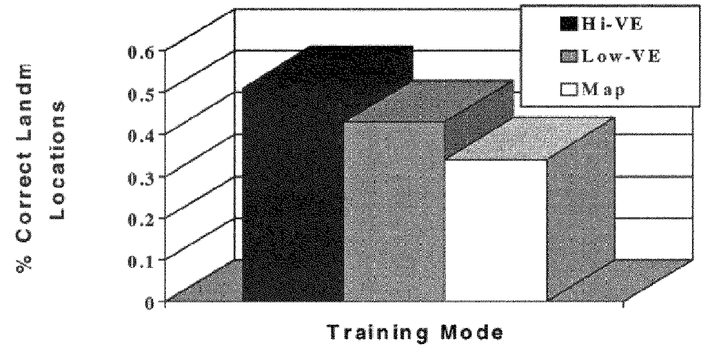

Figure 10. Percentage of landmarks located correctly as a function of training mode

In the second experiment (Singer, Allen, McDonald, and Fober, in preparation), soldiers at Fort Benning, GA performed the same task using a moderate fidelity representation of an actual training area. They used either map study or a mid-level VE interface (head-coupled HMD with joystick control of movement). In addition to being tested in the VE, they were also tested on the actual terrain. The performance of soldiers (Figure 11), when tested in the VE, is consistent with that of the students, although there was only one VE condition. The VE group did better than the map group.

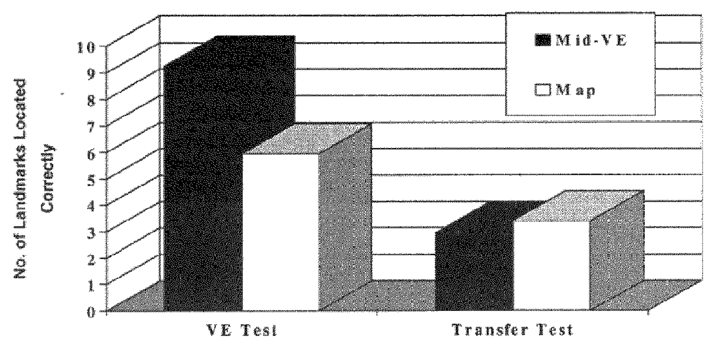

Figure 11. Number of landmarks correct identified by soldiers in VE and on the actual terrain

However, on the transfer test, which was performed on the actual terrain, there was no difference between the groups. Moreover, as is common in studies of transfer of training from simulation devices, both groups did worse on the transfer test than they did on the VE test. There are several possible explanations for this. First, the soldiers were all Army officers who were experienced at relating maps to terrain, but not at relating computer–generated visuals to actual terrain. Second, perhaps the terrain database was not sufficiently like the actual terrain. While it was topographically correct, the color and visual texture were not necessarily correct. Generic plants were photo-textured, and were not the correct height or color. Some re-grading and planting was done, and vegetation grew, between the time the information for the database was collected and the experiment was conducted. Participants may have incorrectly focused on the specific vegetation cues, rather than the terrain contours and roads. This suggests that either lower fidelity (obviously generic vegetation) or higher fidelity (more like the actual views) approaches might be more effective. In contrast to exterior terrain, Witmer, Bailey, and Knerr (1996) found very good transfer of knowledge about building interiors from VE to the real world.

CONCLUSIONS

Conclusions Regarding Visual Display Systems

- VE performance is worse than real world performance on a variety of visual tasks. Contributing factors are likely to be FOV and resolution. The consequences of limited FOV are less well understood than those of limited resolution.
- Distances in VE are typically underestimated.
- Stereoscopic displays improve performance only at short distances.
- Head coupling may or may not improve performance, depending on the task performed.
- Image fidelity is a consideration for transfer.

Conclusions Regarding The Simulation Of Locomotion

- The method used to control self-motion in VE can affect the perception of distance, but not always in the ways we would have predicted.
- Compensatory cues can improve distance perception in VE.
- Because of the influence of computer and video games, young people may be generally proficient in the use of a joystick, and may find it a very "natural" means of locomotion.

REFERENCES

Kline, P.B., & Witmer, B.G. (1996). Distance perception in virtual environments: Effects of field of view and surface texture at near distances. Proceedings of the Human Factors and Ergonomics Society 40th Annual Meeting. Philadelphia, PA. 1112-1116.

Lampton, D. R., Knerr, B. W., Goldberg, S. L., Bliss, J. P., Moshell, J. M., & Blau, B. S. (1994). The virtual environment performance assessment battery (VEPAB): Development and evaluation. PRESENCE, 3(2), 145-157.

Lampton, D.R., Gildea, J.P., McDonald, D.P., & Kolasinski, E.M. (1996). Effects of display type on performance in virtual environments (Technical Report 1049). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Singer, M.S., Allen, R.C., McDonald, D.P., & Fober, G. (1997). Acquisition of spatial knowledge: Map vs. virtual environment. Unpublished manuscript. Orlando, Fl: U.S. Army Research Institute for the Behavioral and Social Sciences.

Singer, M.J., Allen, R.C., McDonald, D.P., & Gildea, J.P. (in preparation). Terrain appreciation in virtual environments: Spatial knowledge acquisition (Technical Report 1056). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Singer, M.J., Ehrlich, J., Cinq-Mars, S., & Papin, J. (1995). Task performance in virtual environments: Stereoscopic vs. monoscopic displays and head-coupling (Technical Report 1034). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Witmer, B.G., Bailey, J. H. & Knerr, B.W. (1996). Virtual spaces and real-world places: Transfer of route knowledge. International Journal of Human Computer Studies, 45, 413-428.

Witmer, B. G. & Kline, P. B. (in press). Judging perceived and traversed distance in virtual environments. PRESENCE.

Witmer, B.G. & Sadowski, W.J., Jr. (in press). Non-visually guided locomotion to a previously viewed target in real and virtual environments. PRESENCE.